Case Report

Complete thoracolumbar fracture-dislocation with intact neurologic function: Explanation of a novel cord saving mechanism

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Background: The thoracolumbar junction from T11 to L2 is a common site of injury in which fracture and dislocations are the most prevalent ones occurring at this location. Fracture dislocation is defined as failure of all three columns of the spine with gross displacement. Considering the significant violence necessary to produce fracture dislocations, these injuries are often associated with major neural deficit, with the majority of casualties becoming paraplegic immediately. Preservation of neurological function following complete fracture dislocation is quite rare entity.

Objective: To represent the possibility of existence of a preservation mechanism for functional integrity of cord despite spinal gross fracture dislocation by reproducing the injury on a plastic model and simulating a corresponding model using 3DSlicer software, detailed description the pathomechanism of neurologic sparing.

Case Report: A 19-year-old female who sustained severe thoracolumbar fracture dislocation but with normal neurology is presented. Despite the severity of the condition, the diagnosis was initially missed due to associated vital injuries.

Results: Combined posterior and anterior surgery resulted in optimal coronal and sagittal alignment, as well as proper stabilization without any complication. At 9-year follow-up, the patient was found to be doing well.

Conclusion: The prognosis for complete recovery with preplanned surgical intervention in thoracolumbar injuries affecting all three columns but with normal neurologic function is promising based on images, plastic models and 3D simulated model based on digital images.

Keywords: 3D-Slicer, Neurological sparing, Spinal injury, Thoracolumbar fracture dislocation

Introduction

The thoracolumbar junction is involved in 15% of all spinal injuries. The anatomic characteristics of this transitional zone provide the condition of least resistance against axial rotation and horizontal translation.[1–5] In the majority of translational or rotational fracture dislocations, the neural arch remains intact; hence, patients with such injuries immediately suffer paraplegia because of severe cord compromise.[1–5] Nevertheless, in certain rare cases of complete fracture dislocation of the vertebral column, the patient remains neurologically normal,[4,6–28] The mechanism of preservation of normal neurologic status is free-floating laminas or the saving fracture of the vertebral arch, in which unilateral or bilateral pedicular shear allows the posterior elements to remain almost aligned, with the ability to preserve the spinal canal integrity and maintain normal neurologic function of the spinal cord, despite gross displacement of the corresponding body.[4,6–28] A careful review of the literature showed that only 6 cases of complete thoracolumbar fracture dislocation with intact neurologic function have been reported previously.[14,15,28–31]

This study represents a case in which a 19-year-old female sustained severe rotational dislocation of L1 on L2, with considerable anterolateral displacement, who nevertheless remained neurologically intact. Furthermore, we found that the pathomechanism of this novel cord saving scenario has been not described before.

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Case report

A 19-year-old female sustained a thoracolumbar spinal injury after falling from a height of about 8 meters. She was brought to the nearest hospital; her chief complaint was abdominal pain. The neurologic examination showed normal results. The lumbar spine in plain abdominal radiographs was interpreted as normal. The next day, the patient underwent laparotomy, which showed contusion of the liver, perforation of the small intestine, and subcapsular hematoma of the spleen. Repair of the perforation and splenectomy were done subsequently. On the 8th postoperative day, the patient complained of back pain of increasing frequency. A review of the initial radiograph showed a problem at the thoracolumbar spine; however, the full extent of the injury was difficult to determine because of the

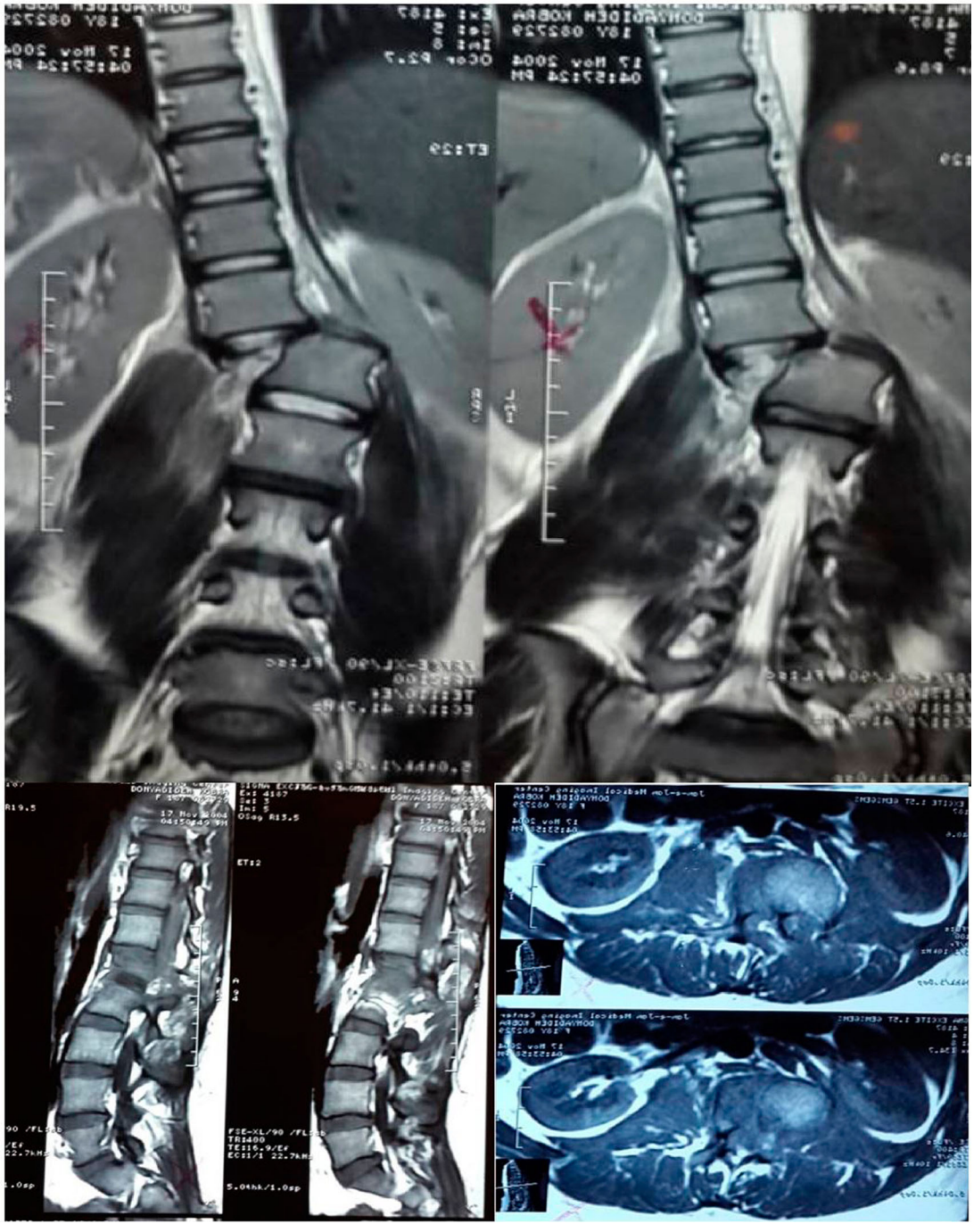

Figure 1 Coronal MR image demonstrating complete fracture dislocation at thoracolumbar region (upper). Sagittal MR image showing marked rotation at thoracolumbar region (lower left), axial MRI showing double body appearance (lower right), note that despite marked dislocation of the bodies, the neural arches are minimally displaced.

presence of shadows from the retained bowel gas, the poor quality of the X-ray images, and the obesity of the patient. Therefore, full spine MRI was done, which showed complete translation of the L1 vertebral body to the left with respect to the L2 vertebral body (Fig. 1).

To better understand the events, axial and reformatted 2D sagittal and coronal and 3D CT scans were done at the site of maximum pathology. Axial CT scan cuts showed a double sun appearance (Fig. 2) The reconstructed two-dimensional CT images showed gross displacement of the L1 vertebral body with respect to the L2 vertebral body; the posterior elements were only rotated and had no displacement (Fig. 3) Reformatted three-dimensional images showed an extremely spectacular injury of the thoracolumbar spine with gross displacement of L1 that was related to its rotation in the forward and left directions with respect to L2. The right posterior inferior corner of the L1 vertebral body was touching the left posterior superior corner of the L2 vertebral body (Fig. 4). Continuity of the spinal processes at the thoracolumbar region was disturbed, with a counter clockwise deviation of the L1 process to the right (Fig. 5) Twelve days after the injury, the patient was transferred to our hospital for surgery.

The mechanism could be explained by reviewing the events on the reconstructed CT images and reproducing the trauma on a plastic model (Fig. 5) as well as on 3D-Slicer software[32] (Figs. 6 and 7); 3D Slicer is a free open source software application for medical image computing. As a clinical research tool, 3D Slicer is similar to a radiology workstation that supports versatile visualizations.[33]

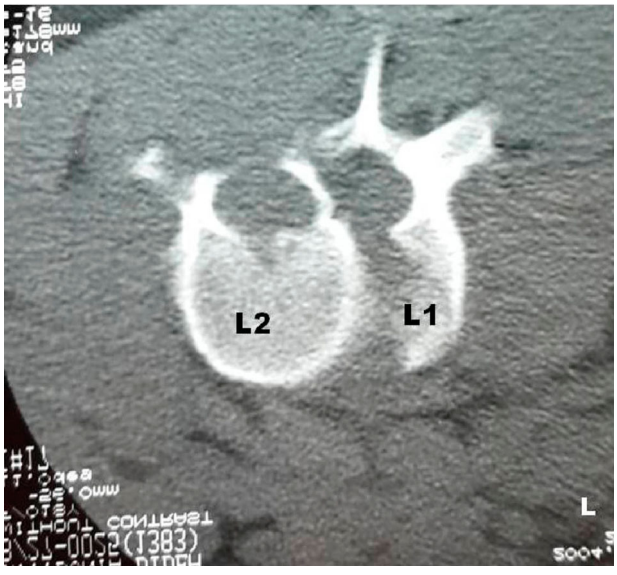

Figure 2 CT scan, axial view revealing double sun set appearance indicating lateral and rotational displacement of L1 with respect to L2.

Technique

Different types of surgery were reproduced on plastic and simulated models. This assisted us in making the decision to surgically apply distraction between L1 and L2 and disengage the locked facets joints with rotational force in clockwise manner. Surgery was accomplished on the 14th post-injury day. With the patient under general anesthesia and in a prone position, posterior spinal fixation with a screw rod construct was performed. Pedicle screws were extended from L1 to T12 cranially and from L2 to L5 caudally. After assembling the rods, we found that reduction was impossible despite the application of distractive forces, probably because of the interference of scar tissues. In order to achieve acceptable alignment, combination of anterior surgery seemed necessary. Therefore, inserted screws of L2

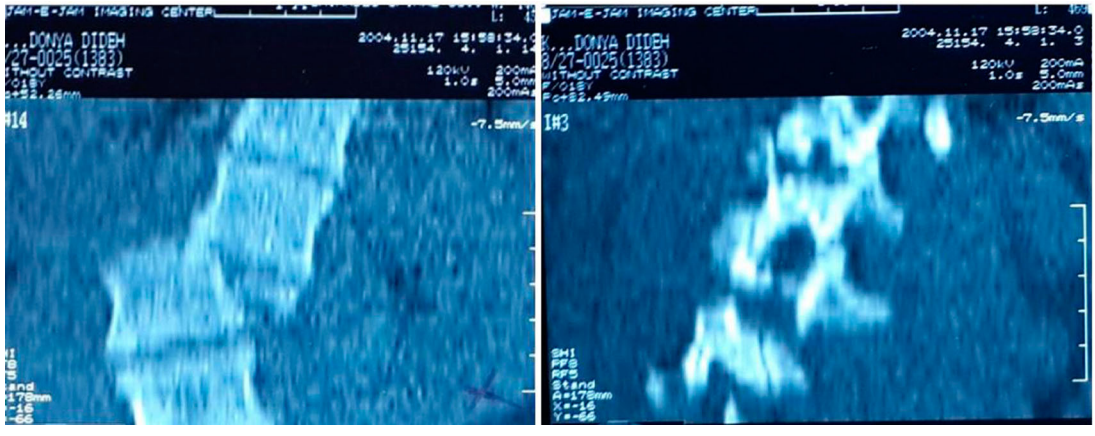

Figure 3 A Two Dimensional C.T: Body of L1 show gross displacement with respect to L2 body (left), posterior elements are intact (right).

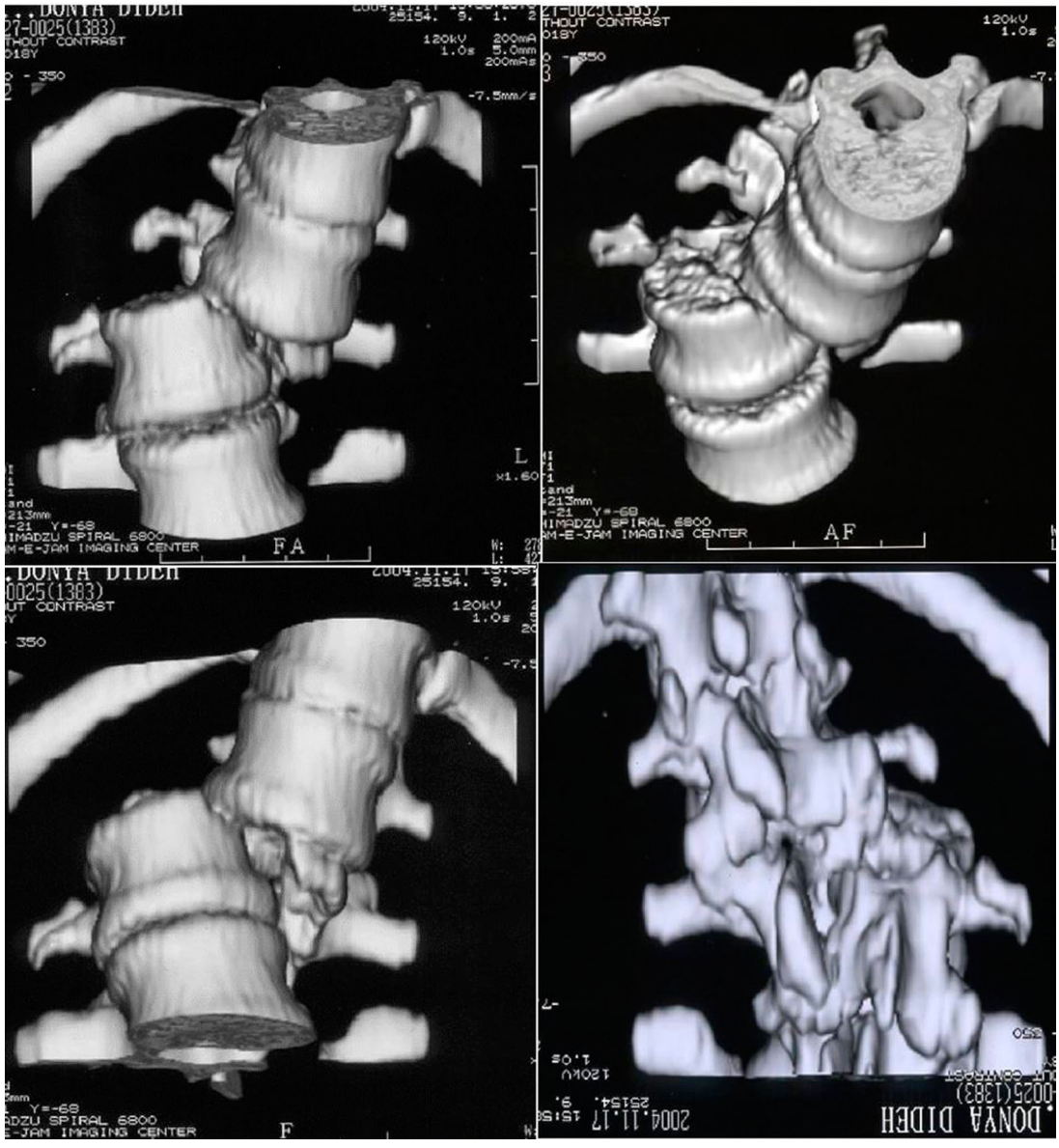

Figure 4 3Dimensional CT scan: Demonstrating lateral displacement of L1 toward the left with respect to l2 vertebral body (upper left, upper right and lower left), the posterior aspect of thoracolumbar region revealing the alignment of posterior element despite gross vertebral bodies displacement anteriorly (lower right).

were removed and subsequently, posterior instrumentation was completed without final tightening of the nuts. Later, with the patient in the right lateral decubitus position and through the left retroperitoneal corridor, the affected vertebral bodies could be targeted in the same stage. At the scene, the L1 vertebral body could be immediately observed, whereas the L2 vertebral body was located relatively deeper with respect to L1. Nonetheless, corpectomy of L2 could be done, and the corpectomized body was replaced with an adjustable cage packed with local autogenous bone graft. However, ultimate alignment could only be obtained after securing the cage with a double rod fixation system anteriorly and tightening of the nuts posteriorly. The procedure was finalized by the application of two cross connectors.

Results

The postoperative course of the patient was uneventful, and she was discharged, walking independently, within a week after surgery (Fig. 8). The postoperative plain radiographs showed good sagittal and coronal alignment (Fig. 9). In the last assessment, 9 years after the injury, the patient had remained completely asymptomatic, with the reconstructed CT images indicating excellent fusion (Fig. 10).

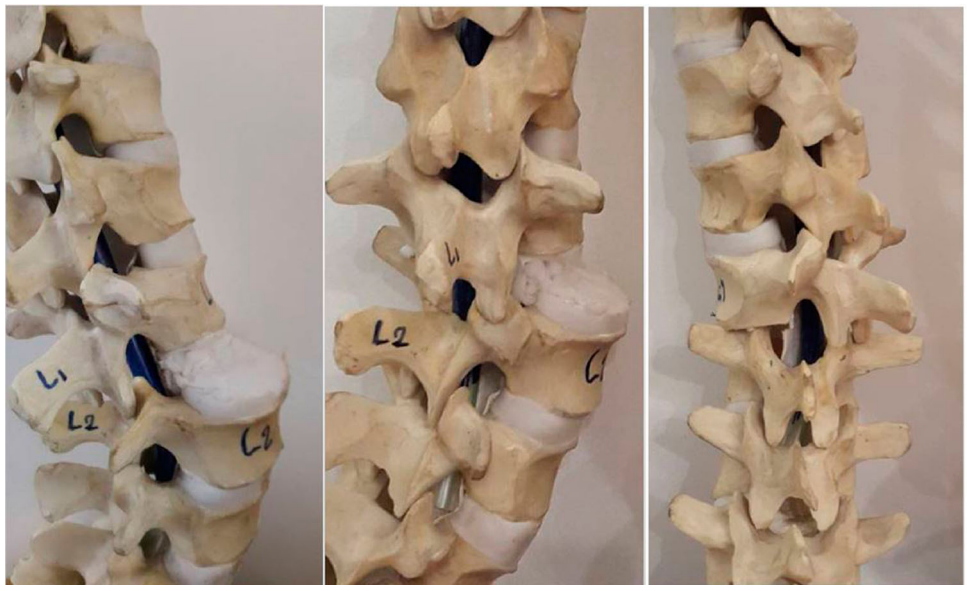

Figure 5 Reproduction of injury on a plastic model shown from the right side: Showing marked displacement and rotation of L1 to the left (left), Note continuation of cord without any impingement. 1 vertebral body is seated on left transverse process of L2 where the inferior facets of L1 are engaged with right superior facet of L2. Note the continuity of the theca (middle). The event shown from the left side, note rotation of L1 (right).

Discussion

The thoracolumbar junction from T11 to L2 is a common site of injury because there is a transition from the relatively stiff and kyphotic thoracic spine above to the relatively mobile and lordotic lumbar spine below.[1–5,34] Typically, the patients who sustain thoracolumbar spine injury are young subjects between the ages of 15 and 35 years, who get involved in a motor vehicle accident or fall from a height.[1–5,34] Twenty percent of major spinal injuries occurring at this location are fracture and dislocations.[2,5,30,34–36] Fracture dislocation is defined as failure of all three columns of the spine with gross displacement.[5,10,30] Considering the significant violence necessary to produce fracture dislocations, these injuries are often associated with major neural deficit, with the majority of subjects incurring paraplegia immediately.[1,2,4,5,10,34,36,37]

In the present case, after considering the reconstructed CT images, we reproduced the trauma on a plastic model with reconstruction of the event using 3D-Slicer (Open Source Software,Brigham and Women's Hospital, Inc., Boston, MA, USA).[33] It has been interpreted that a mechanism other than saving fractures could have protected the cord despite the near-complete dislocation. Eventually, occurrence of such spectacular injury could have resulted from violent posterior/anterior hyperflexion, in combination with a shearing rotational injury crossing the intervertebral L1-L2 disc.

Continuation of the shearing injury, accompanied by rotational forces with the spinal cord as a hinge, led to the corresponding facet joints becoming engaged and locked, with the spinal canal remaining aligned. Nonetheless, the current case was treated with combined posterior and anterior fusion and fixation. At 9-year follow-up, our patient was symptom-free and doing well. As conditions are represented in Figs. 5,6, and 7, it can be suggested that in a certain rare circumstances and despite significant front/back or lateral displacement of the vertebral bodies, a person might remain neurologically intact or might be only mildly affected.

During recent decades, there have been several reports of severe fracture-dislocations of the spine in which the spinal cord sustained much less damage than the bony displacement would have led one to expect, including 18 cases of complete thoracic fracture dislocation with normal neural function[10–18,20,21,25,27] and eight reported cases of low lumbar region.[6,8,9,22,24] However, surprisingly, despite the susceptibility of the thoracolumbar region to high-energy traumas and the high frequency of complete fracture dislocation in this region, neurologic sparing in such injuries was observed only in six cases.[13,14,17,19,28] Nonetheless, the explanation for such neural sparing is quite interesting because of the large discrepancy between such spectacular radiologic features and the neurologic function.

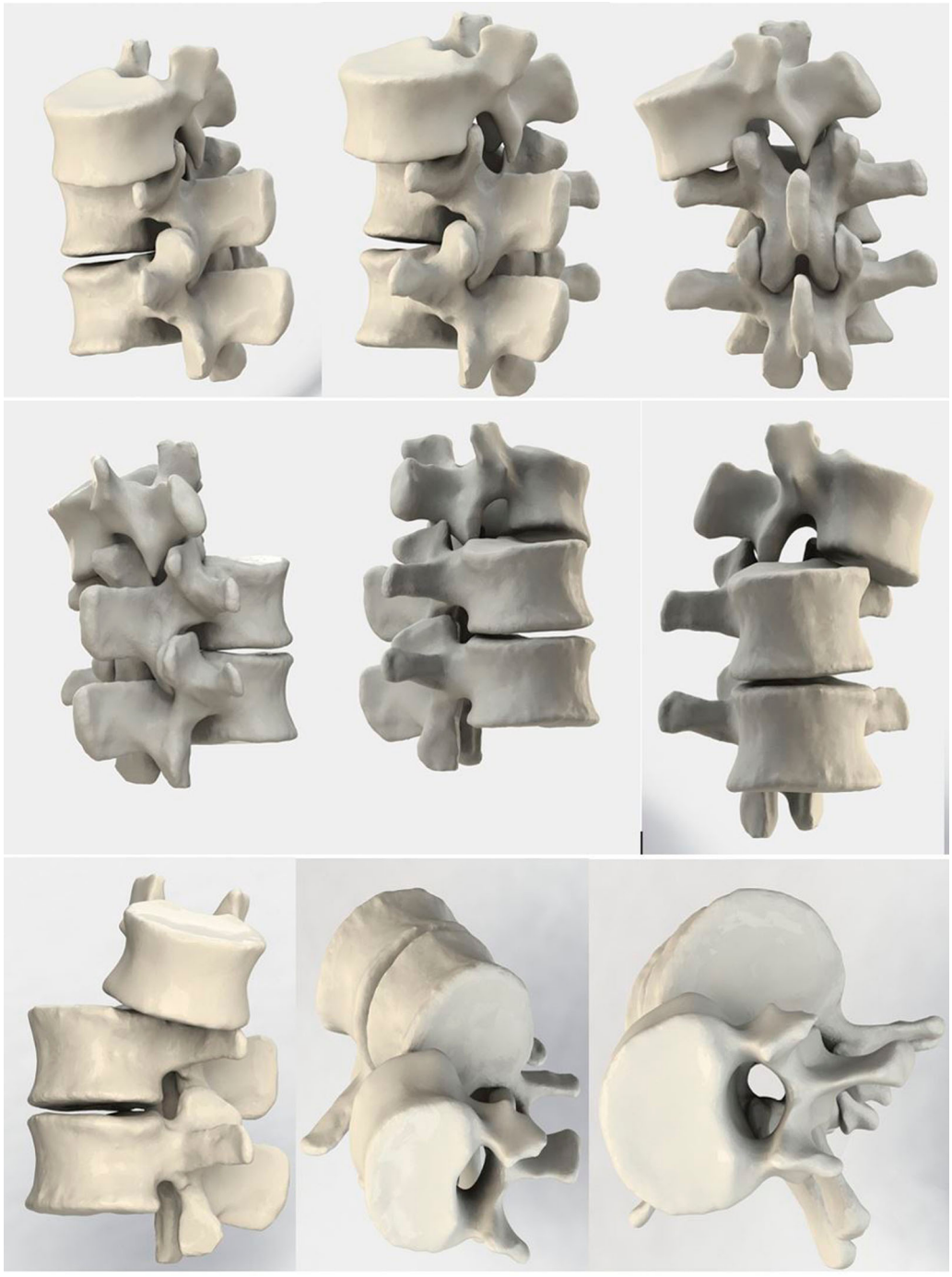

Figure 6 Representation of a simulated 3D rendered model based on CT images to reproduce the scenario (3D-Slicer software): different viewpoints are prepared in favor of a comprehensive understanding of scenario; the last sub-Fig. (third row, third column) indicates that despite the complete and remarkable dislocation, canal has remained open.

The possibility of the existence of a preservation mechanism for functional integrity of the spinal cord despite gross fracture dislocation has been reported previously.[1,13] Since then, five more cases of complete fracture dislocation of the thoracolumbar spine with normal neurologic function have been published,[13,17,19,23,28,29] with our case presentation being the seventh example of this type in the literature (Table 1).

The common premise in all previously reported cases was that shearing force resulted in the fracture of one or both pedicles, allowing the separation of the posterior elements from the body, along with discoligamentous disruption, with significant forward or lateral displacement and even spondyloptosis. However, in our patient, dislocation occurred without any fracture.

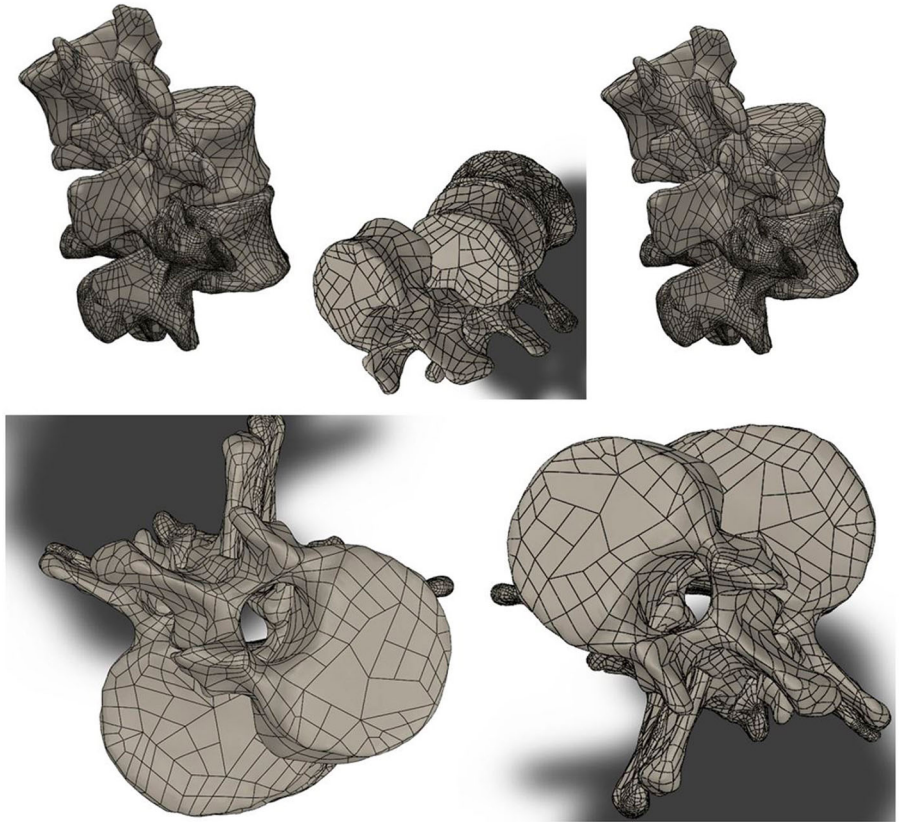

Figure 7 Representation of a simulated 3D networked model including finite elements (mesh), based on rendered models presented in Fig. 6; different viewpoints are prepared (again) in favor of a comprehensive understanding of scenario in which, elements may be helpful to consider conditions in detail; these sub-figures (especially lower left and lower right) indicate that despite the complete and remarkable dislocation, canal has remained open.

Bohler classified fracture dislocation into two types. The first type is fracture dislocation with saving fractures, as described previously.[34] The second type includes cases with translational or rotational dislocation without fracture of the neural arch, pedicles, or vertebral body, which is quite similar to our case report. However, this type is accompanied with high incidence of paraplegia. This means that the preservation of neural function in the current case is an exception or a medical curiosity.

The explanation of the mechanism of injury in our case requires a brief review of the literature. For gross lateral dislocation, substantial force is required to produce failure in the spinal region. As Roaf *et al*. stated, the thoracolumbar region is highly vulnerable to rotational and shear forces.[36] Accordingly, for a fracture dislocation to occur, a combination of hyperflexion and rotational force is necessary to cause failure of all three columns.[35] Denis divided shear injuries into two types: posteroanterior and anteroposterior.[36] Anteroposterior forces are induced by hyperextension forces, resulting in fractures of the posterior column and pedicles, with a free-floating neural arch. However, a violent posteroanterior force causes hyperflexion, and, in combination with rotational shearing force, the body is displaced laterally.[36] In our case, to understand the pathomechanism leading to such a rare constellation of severe fracture dislocation but without neural damage, a review of the three-dimensional CT scan features and the reproduction of the injury on a plastic model seemed necessary.

These events could be easily rebuilt by the hyperflexion of L1 with respect to L2 and with additional rotations of L1 to the left, similar to the force produced by a posteroanterior shear.[35,36] Initially, with flexion distraction, the inferior facets of L1 jump and separate from the superior facet joints of L2. Subsequently, with a counter clockwise rotation of the vertebra, the L1 vertebral body is displaced to the far left, at which the left inferior facets of L1 pass over the right superior facet of L2. Once the injury settles, these facet joints become locked into each other. In such events, the spinal cord acts as a hinge and remains intact.

Despite the severity of complete fracture dislocations severity, this type of trauma might be neglected, once

Figure 8 The patient wearing a brace has stood on tip-toes in order to show her neurological function a month after surgery.

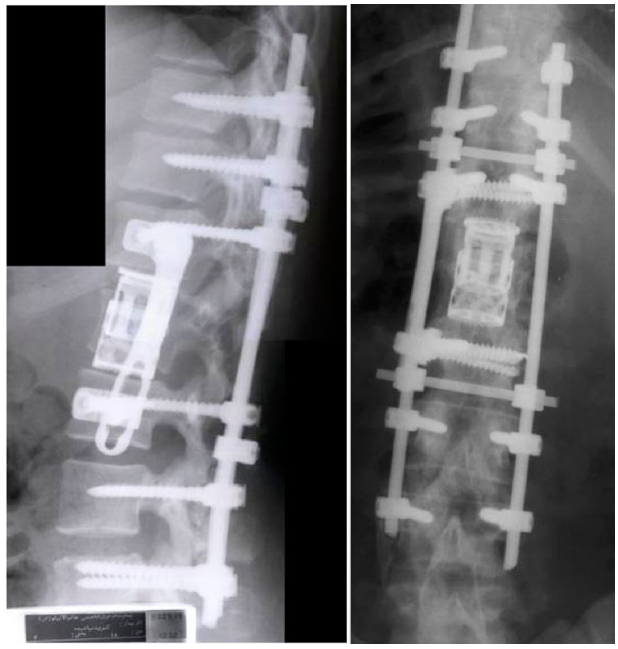

Figure 9 Postoperative AP and lateral radiographs at 9-year follow-up: (Left and Right) showing good alignment and fusion.

the neurological function is normal. In a review of 13 cases with this type of injury at thoracic spine Lijenqvist *et al*. found that the injury was initially missed in four patients despite their immediate admission to the hospital.[16] The most important cause of possible delay and negligence was the absence of prominent neurologic deficit. Another major cause of missing the injury and delayed diagnosis of spinal injury was the presence of an associated life-threatening injury necessitating emergent intervention, particularly in polytrauma patients.[15,16] Another common cause is inadequate radiologic survey, such as failure to obtain adequate or good-quality plain radiographs that may not show the spinal injury properly. Hopefully, most patients with saving fractures would remain neurologically intact despite their periodic positioning and even frequent transportation, which are necessary for imaging assays of other affected organs. Furthermore, in cases similar to our patient, the engaged facet joints might provide relative stability, as was observed in the reproduction and during the surgery. Nonetheless, disastrous neurologic deficit might occur if the patient tries to stand or is forced to walk around after recovery from a coexisting initial serious injury.

Although these injuries can be suggested on plain films, full spine MRI remains the diagnostic tool of choice for detecting spinal injuries.[11,12,21] MRI can show the continuity of the theca and, in particular, the

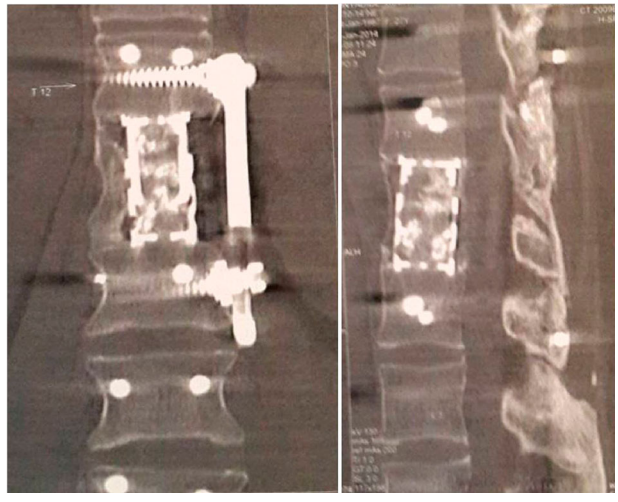

Figure 10 Postoperative reconstructed sagittal and coronal CT at 9-year follow-up: (Left and Right) showing perfect fusion between L1 and L3.

Table 1 Review of complete fracture dislocations at thoracolumbar region with normal neurology or with mild neurological dysfunction.

Author(s)	Year	Sex	Age	Location	Surgery	Outcome
Guttman[13]	1976	?	?	TL	None; only conservative	Good
Yazici *et al.*[28]	1999	F	6	L1-L2	Posterior Rod + Wire	Good
Akay *et al.*[7]	2003	M	21	T12-L1	Posterior Screw Rod Fixation	Good
Phadnis *et al.*[19]	2006	M	21	L1-L2	Combined Posterior Screw Rod + Anterior	Good
Hsieh *et al.*[29]	2008	M	50	T12-L1	Posterior screw rod instrumentation	Good
Sugiura *et al.*[23]	2016	M	18	T12-L1	Anterior only fusion instrumentation	Good
Current case	2016	F	19	L1-L2	Combined posterior Screw Rod + Anterior	Good

integrity of the cord in free-floating laminas.[19] However, in hyperflexion rotation injuries, the continuity of the cord can be hard to establish because of the marked rotation.

Once the site of injury has been confirmed in the MRI, the use of CT is almost always preferred in defining the extent of the injury. Many characteristic signs of fracture dislocations can be observed on axial CT images depending on the degree of displacement: In the axial view, the "double rim" is the most striking feature representing relative displacement of one vertebral body over another, whereas the "double sun" is observed in complete fracture-dislocation.[15,16,21] Thus, two- and three-dimensional reconstructed CT scans are of great help in understanding the mechanism of the injury and can also assist the surgeon in correct decision-making.[8,19] Once the diagnosis of complete fracture-dislocation of the thoracolumbar spine is made, proper surgical management is warranted. The primary goal of surgery in these complex injuries is restoration of the anatomic alignment and spinal stability with preservation of cord function integrity.[1,2,5,34,35,38,39]

The diagnosis of and surgical intervention in the cases similar to our case within a few days after the injury is ideal where the overriding of the vertebral bodies can be aligned with effective intraoperative distraction.[15,16,21] Considering the severe ligamentous injury observed in such cases, the posterior approach with distraction applied to the screws cranial and caudal to the lesion is able to reduce the lesion.[15,16,21] The achievement of sufficient reduction relies on the controlled amount of distraction applied between the corresponding pedicle screws; over-distraction will endanger the cord function. Neuro-monitoring is proposed to prevent unintended injury to the cord during the distraction necessary for reduction. In the past, the preoperative application of pelvic traction to patients and its continuation during surgery to facilitate reduction were advised.[39] Preoperative traction does ameliorate spinal column shortening and prevent soft tissue contraction around the lesion.[39] However, with the introduction of pedicle screws, this method is rarely used. Early surgery with reduction and stabilization allows the early mobilization of the victim and protects the neural tissues from further injury.

For complex thoracolumbar fractures, multiple reports have shown that posterior distraction should be carried out ideally within three to five days from the time of injury.[16,19] With delayed treatment because of the scar formed around the lesion, reduction of the displaced vertebral body can hardly be achieved with distraction applied through the posterior approach. Moreover, the maneuver and surgical reduction are risky and might endanger the integrity of the cord. In such circumstances, alignment can be achieved with combined back and front surgery. After pedicle screw instrumentation and partial reduction, the patient is flipped to the lateral decubitus for corpectomy. After corpectomy, the gap is replaced by a strut graft or an expandable cage. At present, in chronic cases, and with the introduction of posterior-only procedures, posterior instrumentation, corpectomy, and cage placement can be done by applying this new method. Nonetheless, in complete thoracolumbar fracture dislocations, particularly those with delayed diagnosis, the surgical decision- making should always be tailored to the individual case.[31] With proper diagnosis and surgery, the ultimate outcome is promising, and the patient usually returns to his or her normal activities within a few months postoperatively.

In summary, severe thoracolumbar injury might be associated with neural sparing, if the middle column is separated from the body. In rotational flexion distraction injury, as was observed in the current case, the spinal cord, acting as a pivot, might remain intact despite severe rotation and translation.

Finally, as a conclusion, we suggest that thoracolumbar injuries affecting all three columns but with normal neurologic function might be missed and neglected, particularly if the attention of the surgeon is drawn to other more obvious injuries. The prognosis for complete recovery with surgical intervention in such cases is promising.

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Disclaimer statements

None.

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